INDOOR AIR QUALITY ASSESSMENT

Quarry Hill Community School
43 Margaret Street
Monson, Massachusetts

Prepared by:
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Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program

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Background/Introduction

At the request of the Monson School Department and a parent, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality issues and health concerns at the Quarry Hill Community School (QHCS), 43 Margaret Street, Monson, Massachusetts. On May 21 and 28, 2004, visits to conduct indoor air quality assessments were made to this school by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA.

The school is a multi-wing, single-story brick building originally constructed in 1991. The school was configured in a Maltese cross configuration with four wings radiating from a three-story atrium at the center of the complex (Cover Photo). The school contains general classrooms, library, cafeteria, teachers' lunchroom, administrative offices, nurse's office and conference rooms. One wing contains the gymnasium, mechanical room and a pool. Hallways and most classrooms have wall-to-wall carpeting that was installed when the building was constructed (+13 years in age). Windows are openable throughout the building.

Methods

BEHA staff conducted a visual inspection for standing water, water-damaged building materials and microbial growth. Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520.

Screening for total volatile organic compounds (TVOCs) was conducted using an HNu Photo Ionization Detector (PID). Water content of carpeting was measured with a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe.

Results

The school houses a sixth through eighth grade student population of approximately 600 and a staff of approximately 50. Tests were taken during normal operations at the school and results appear in Tables 1-3.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million (ppm) in one of nineteen areas surveyed on May 21, 2004 and twenty of forty-nine areas surveyed on May 28, 2004, indicating ventilation problems in several areas of the school. A number of classrooms had open windows or were sparsely occupied during both visits, which can greatly reduce carbon dioxide levels.

Fresh air in classrooms is provided by unit ventilators (univents) (Figure 1, Picture 1). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an intake located at the base of each unit. The mixture of fresh and return air is drawn through a filter and heating coil and provided to the classroom from the univent by motorized fans through an air diffuser on the top of the unit. Univents were operating in all areas surveyed; however, a number of units were obstructed, preventing airflow. To function as designed, univent diffusers and returns must remain free of obstructions.

The mechanical exhaust ventilation system consists of ceiling-mounted exhaust vents. These vents were operating throughout the building. The location of some exhaust vents near classroom doors can limit exhaust efficiency. When a classroom door is open, exhaust vents will tend to draw air from both the hallway and the classroom. The open hallway door reduces the effectiveness of the exhaust vent to remove common environmental pollutants from classrooms.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, consult Appendix A.

Temperature measurements ranged from 76° F to 79° F on May 21, 2004 and from 70° F to 78° F on May 28, 2004, which were within the BEHA recommended comfort range in most areas. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measured in the building ranged from 46 to 56 percent on May 21, 2004 and from 52 to 65 percent on May 28, 2004, which were within the BEHA recommended comfort range on both days, with the exception of the pool hallway (65%). The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Of note was the relative humidity measurement of 65 percent in the hallway outside the pool, which exceeded outdoor measurements by 7 percent (May 28, 2004). This measurement, as well as the odor of chlorine detected in hallways, indicates that both air and moisture are penetrating into other occupied areas of the school from the pool area. The increase in relative humidity can indicate that the pool exhaust system is not operating sufficiently to remove air pollutants (e.g., water vapor and chlorine odor). Moisture removal is important to prevent the chronic wetting of porous materials (e.g., carpeting), which can result in fungal growth. Moisture removal is also important since the sensation of heat conditions increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperatures rise, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is increased. While temperature is mainly a comfort issue, relative humidity in excess of 70 percent can provide an environment for mold and fungal growth (ASHRAE, 1989). During periods of high relative humidity, the pool exhaust ventilation system should be operated continuously, windows and exterior doors should be closed to keep moisture out and univents and exhaust ventilation should be activated throughout the school to control moist air in the building.

Microbial/Moisture Concerns

Of note is the lack of roof gutters and downspouts along the sloped roof of the building. The exterior of a number of wings had extensive moss growth on the building apron, brick and pilasters (Pictures 2 through 4). A substantial source of water is needed for moss to grow. The source appears to be rainwater pouring from the roof onto the tarmac below. As a result of chronic water exposure, the soil beneath this area has become compressed, resulting in the tarmac becoming pitched towards the building. On May 28, 2004, the building was examined during a heavy rainstorm during which water had accumulated in deep pools against the building (Picture 5).

In an effort to examine whether pooling water was entering the building, moisture sampling was conducted in classroom carpeting. The moisture sampling was undertaken after the following conditions were discovered in rooms 315 and 316 during the May 21, 2004 visit:

- Carpeting over the exterior wall/slab junction in room 316 pulled away easily from the floor. This indicates that the adhesive was exposed to moisture, which degraded its ability to adhere the carpet to the slab.
- Carpeting in room 315 resisted pulling because of repeated application of carpet mastic. The thick application of carpet adhesive indicates that the carpet in this room had separated from the floor in an area along the exterior wall/slab seam.

- An open seam between the exterior wall and slab (width approximately 4 centimeters) was seen in rooms 315 and 316 (Picture 6) directly beneath the carpet.
- Insect bodies were under the carpet, indicating a means of ingress from the outdoors. The most likely means of ingress appeared to be the wall/slab seam. (Note: a live insect was seen entering the crack during the assessment).
- A cementitious material appeared to be applied between the exterior wall and the slab on the outside of the building. Cracks around this material were found, which may serve as a means for insects and water vapor to enter the building. Other cracks were noted in wall seams. School staff reported that cracks in classrooms appeared during construction of the new high school north of the QHCS (Maps 2-4). The combination of blasting during the construction of the new high school combined with the heavy snow load carried by the building structure during the winter of 2002-2003 may have played a role to open the seams and cracks observed.

Based on these observations, Mr. Feeney returned to the building to complete air testing in the building and to conduct moisture sampling of building materials, with a focus on wall-to-wall carpeting.

In an effort to ascertain moisture content of carpeting, measurements were taken in rooms throughout the building at three intervals. A Delmhorst probe was inserted into the surface of carpeting 1) directly over the wall/slab seam, 2) approximately 3 feet in from the seam, and 3) if moisture was measured in carpeting approximately 3 feet from the seam, a third reading was taken approximately 5 feet from the seam. If a source of moisture were atmospheric (e.g., increase relative humidity), moisture readings in carpet would be expected to be uniform (i.e., with a narrow variation of $\pm$ 2%). Where a significant variation exists in moisture content (e.g., one section of carpet measures non-detectable for moisture, another section measures 10%), it could be concluded that another source of water is moistening the carpet.

The moisture sampling was conducted on May 28, 2004, which was an initially rainy day that cleared in the afternoon, with an outdoor temperature of 68 ^{o} F and relative humidity of 58 percent. No active leaks were observed and no visible, accumulated moisture was noted on carpets, walls or ceilings. Relative humidity indoors was measured in a range of 52 to 65 percent (Table 2). Moisture readings are listed by room in Table 3 in a range from the lowest to the highest moisture concentration reading. A total of 26 rooms were evaluated. Of those 26 rooms, 21 had moisture measurements above the wall/slab seam, which tapered down to non-detectable 3 feet from the wall in most rooms. Cement in seams was measured in some rooms that had moisture concentrations greater than cement measured in interior hallways. In both cases, it appears that moisture is accumulating and penetrating though the wall/slab seam, which in turn moistens the carpet.

During the winter of 2003-2004 New England experienced record cold temperatures. If cold air penetrating through the seams of the exterior wall comes in contact with warm building materials (e.g., walls/slab), condensation can generate. Condensation is the collection of moisture on a surface that has a temperature below the dew point. The dew point is a temperature that is determined by air temperature and relative humidity. As an example, at a temperature of 70^{o} F and relative humidity of 25 percent indoors, the dew point for water to collect on a surface is approximately 32° F (IICR, 2000). Therefore, any surface that has a temperature below 32° F (e.g., the seam and backing of the carpet) would be prone to condensation generation under these temperature and relative humidity conditions. The mean measured temperature was below freezing ($<32^{\circ}$ F) from January 4, 2004 through February 3, 2004 (The Weather Underground, 2004) for greater Monson, MA. Assuming an average indoor temperature of 70° F and an outdoor temperature of $\leq 32^{\circ}$ F, any surface that is chilled to a temperature below freezing indoors (e.g., the carpet backing in contact with outdoor air) would be prone to generate condensation in areas with a relative humidity greater than 25 percent (which is typical inside a school during the heating season in Massachusetts). Therefore, condensation would be expected to accumulate in the wall/slab seam and on the wall-to-wall carpeting at the seam during this cold weather time frame (~30 days) and not have an opportunity to dry.

The American Conference of Governmental Industrial Hygienists (ACGIH) and the U.S. Environmental Protection Agency (US EPA) recommends that carpeting be dried with fans and heating within ***24 to 48 hours of becoming wet*** (ACGIH, 1989; US EPA, 2001). If carpets are not dried within this time frame, mold growth may occur. Water-damaged carpeting cannot be adequately cleaned to remove mold growth. Since the carpeting was likely wet from both penetration of accumulated rainwater and condensation during below freezing weather, it was likely that the carpeting had become colonized with mold, which was confirmed by the musty odor detected in carpet backing pulled from the floor by BEHA staff.

As discussed previously, moisture from the pool area appears to be migrating into adjacent areas of the building. High relative humidity can cause the accumulation of moisture on surfaces that have a temperature lower than the ambient air temperature (e.g., cement slab). If the floor of hallways is prone to moisture accumulation, carpeting should not be used as a floor covering. In this instance, the combination of the hot, humid weather with the additional presence of water vapor from the pool may have moistened hallway carpeting, resulting in mold colonization. Cleaning of carpets is not generally effective for removing mold.

The operation of univents can provide a potential means for distributing mold, spores and other particulates into other areas of the building. Facilitating the distribution of these materials is the design of the QHCS. Univents at the QHCS are equipped with filters that provide minimal removal of respirable dusts. Univents also had spaces and holes within their air handling cabinets. The presence of these holes allows for air to by-pass filters, resulting in aerosolization of materials (e.g., dust). In this instance, materials, such and mold, spores (from carpeting) and other pollutants can be drawn into the univent and distributed throughout the classroom. These materials can then be drawn into the hallways by airflow created by the design of the building. Each wing has hallways that radiate from a central, multi story, glass-topped atrium. As heated air rises up into the glass ceiling of the atrium, air is drawn from the hallways. Hallways do not have mechanical fresh air supply or exhaust vents. It appears that the HVAC system was designed to have univents over pressurize classrooms forcing air into hallways through undercut doors, which is then drawn toward the atrium. If airborne pollutants exist in the classroom air, they can then be drawn into the hallways towards the atrium, in a manner similar to the chlorine odor from the swimming pool detected in the atrium and hallways.

Of note was carpeting at the end of hallways near exterior doors. Water damage to the doorframes indicates that wall-to-wall carpeting installed around the threshold may become regularly moistened, most likely during wind–driven rain or drifting snow. Splashing rainwater along the perimeter of the building can lead to chronic moistening of exterior walls and doors, which in turn moistens carpeting installed against the doorframe.

Several classrooms contained a number of plants. Plant soil and drip pans can be a source of mold growth. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen or mold. A classroom contained a salt-water aquarium on top of a table. Aquariums should be properly installed to prevent moisture accumulation through condensation generation, particularly on the underside. Insulation or elevation to allow for airflow to dry beneath the aquarium is recommended. In addition, appropriate ventilation is necessary to remove odors associated with salt-water aquariums.

Other Concerns

Indoor air quality can also be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less

(PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter. As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were ND or non-detect (Tables 1 and 2). Carbon monoxide levels measured in the school were also ND.

The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 45 $\mu g/m^3$ on May 21, 2004. PM2.5 levels measured indoors ranged from 40 to 65 $\mu g/m^3$. Outdoor PM2.5 concentrations on May 28, 2004 were measured at 5 $\mu g/m^3$ and PM2.5 levels measured indoors ranged from 3 to 65 $\mu g/m^3$. A single PM2.5 indoor measurement of 112 was also taken on May 28, 2004 (Table 2). This measurement can be attributed to children's activities on the carpet, as well as their movement to form a queue. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC measurements throughout the building were also ND (Tables 1 and 2).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products (e.g., the concentration of TVOCs within a classroom increases when the product is in use). Of note is the use of individually purchased cleaning materials in the QHCS. Cleaning materials frequently contain ammonium compounds or sodium hypochlorite (bleach-products), which are alkaline materials. The use of these products can provide exposure opportunities for individuals to a number of chemicals, which can lead to irritation of the eyes, nose or respiratory tract.

A number of other conditions that can potentially affect indoor air quality were also observed. Some classrooms have grains and in one instance, popped popcorn in open bins. The use of former food storage containers was also seen in some classrooms. Reused food containers and poorly stored food can create conditions to attract pests into the building. Under current Massachusetts law (effective November 1, 2001), the principles of integrated pest management (IPM) must be used to remove pests in state buildings (Mass Act, 2000). Pesticide use indoors can introduce chemicals into the indoor environment that can be sources of eye, nose and throat irritation. The reduction/elimination of pathways/food sources that are attracting insects should be the first step taken to prevent or eliminate infestation.

A number of classrooms contained upholstered furniture. Upholstered furniture is covered with fabric that comes in contact with human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. In addition, if relative humidity levels increase above 60 percent, dust mites tend to proliferate (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, 1994). It is also recommended that upholstered furniture (if present in schools), be professionally cleaned on an annual basis. If an excessive dusty environment exists due outdoor conditions or indoor activities (e.g., renovations), cleaning frequency should be increased (every six months) (IICR, 2000). Elevated outdoor levels of airborne particulates can result in increased levels of indoor particulates by entering into the building through open windows, doors and filter bypass.

Finally, was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Conclusions/Recommendations

BEHA staff conducted indoor environment evaluations with a primary focus on identifying possible environmental sources that can create conditions conducive to mold growth. If occupants continue to report indoor air quality -related after implementation of the recommendations listed in this report, then consultation with an environmental/occupational physician may be considered.

The general building conditions, design, work hygiene practices and the operation of HVAC equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons a two-phase approach is required, consisting of **short-term** measures to improve air quality and **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Remove wall-to-wall carpeting from wall/slab seam in all classrooms by at least three feet (five feet in classrooms with measurable moisture) (Table 3). Disinfect slab areas with an anti-microbial. Install a runner along the carpet edge.
2. Remove all plant and moss growth along the building exterior.
3. Seal the wall /slab seam inside classrooms with an appropriate sealing compound to prevent cold air/moisture penetration.
4. Reestablish the seal between the slab and exterior curtain wall to prevent air and water penetration.
5. Replace walk-off mats at the end of hallways with a non-porous material (e.g., tile with a rubber tread mat).
6. Consult with a ventilation engineer concerning the repair and operation of the pool exhaust system. The pool exhaust system should be operating 24 hours a day to remove water vapor and chlorine odors from the building.
7. Remove all obstructions from univent air diffusers and return vents to facilitate airflow.
8. Increase the efficiency of filters in univents. Consult with a ventilation engineer concerning the increase in filtration.
9. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in

conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

10. Consider reducing the number of plants and move away from univents. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.

11. Reduce the use of cleaning materials that contain respiratory irritants (bleach and ammonia related compounds) on floors and in classrooms. Do not use these materials to disinfect equipment that comes into close human contact (e.g., telephones). Substitute plain soap and hot water for ammonia related cleaning products. Cleaning products that contain ammonia should only be used where necessary. If a bleach or ammonia containing cleaning product is used, rinse the area of application with water to remove residue.

12. Insulate bottom or elevate salt-water aquarium to prevent condensation. Ensure proper exhaust ventilation is provided to remove odors and excess moisture.

13. Use the principles of integrated pest management (IPM) to rid this building of pests. A copy of the IPM recommendations (MDFA, 1996) can be downloaded from the following website:
http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf.

14. Reduce the amount of items stored in classrooms to provide cleanable surfaces.

15. Clean upholstered furniture on the schedule recommended in this report. If not possible/practical, remove upholstered furniture from classrooms.

16. Consult *Mold Remediation in Schools and Commercial Buildings* published by the US EPA (2001) for more information on mold. Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.

17. Consider adopting the US EPA document, *Tools for Schools* (US EPA, 2000b), as a means to maintaining a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

18. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: http://www.state.ma.us/dph/beha/iaq/iaqhoFtme.htm.

Long-Term Recommendations

1. Reestablish the slope of the building apron to direct rainwater away from the building.

2. Consider installing a gutter and downspout system along the entire edge of the sloped roof to prevent water accumulation along the building exterior. Increase the capacity of existing gutters and downspouts to drain.

3. Consider replacing all wall-to-wall carpeting in the building with a non-porous flooring surface.

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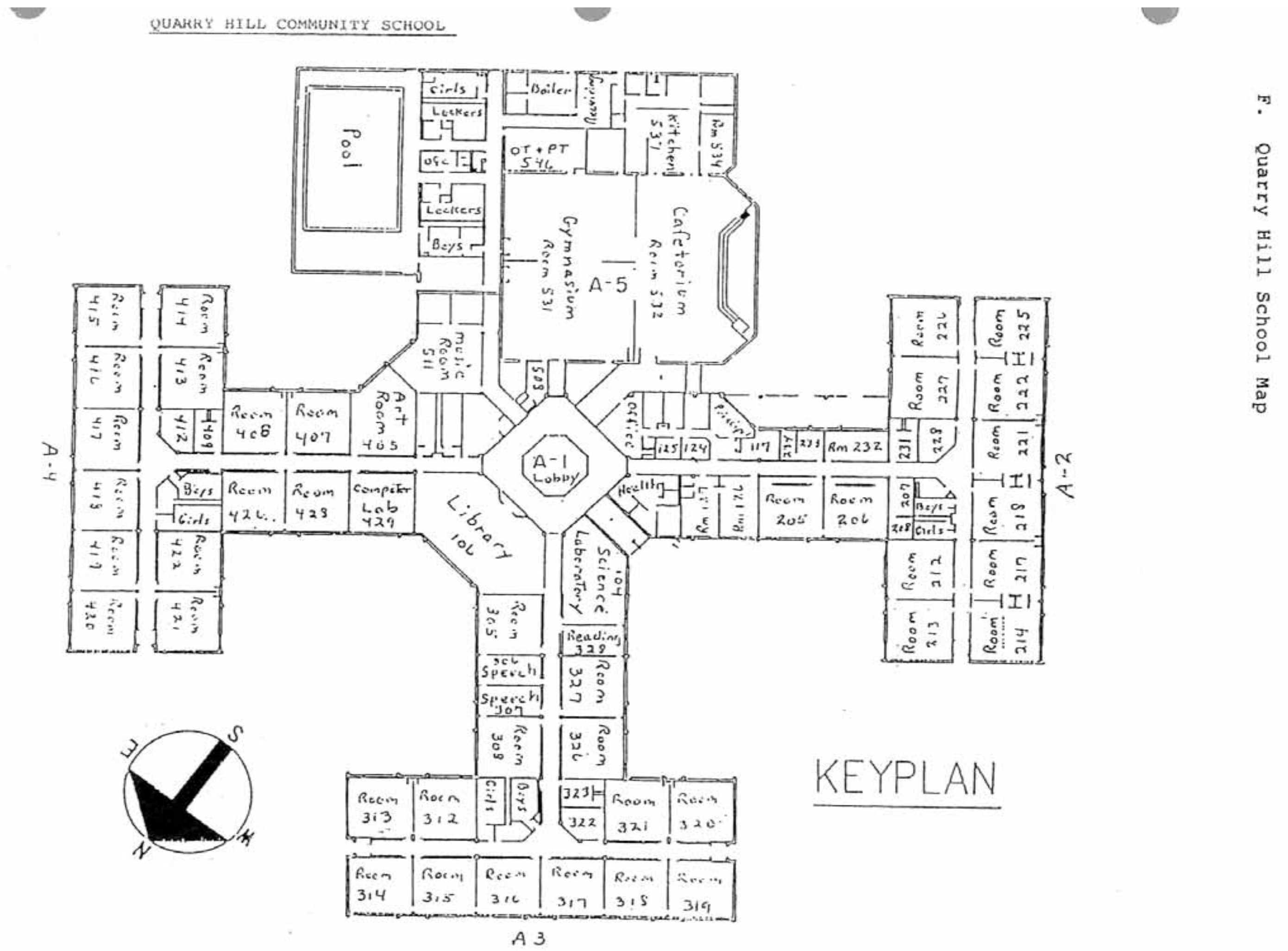
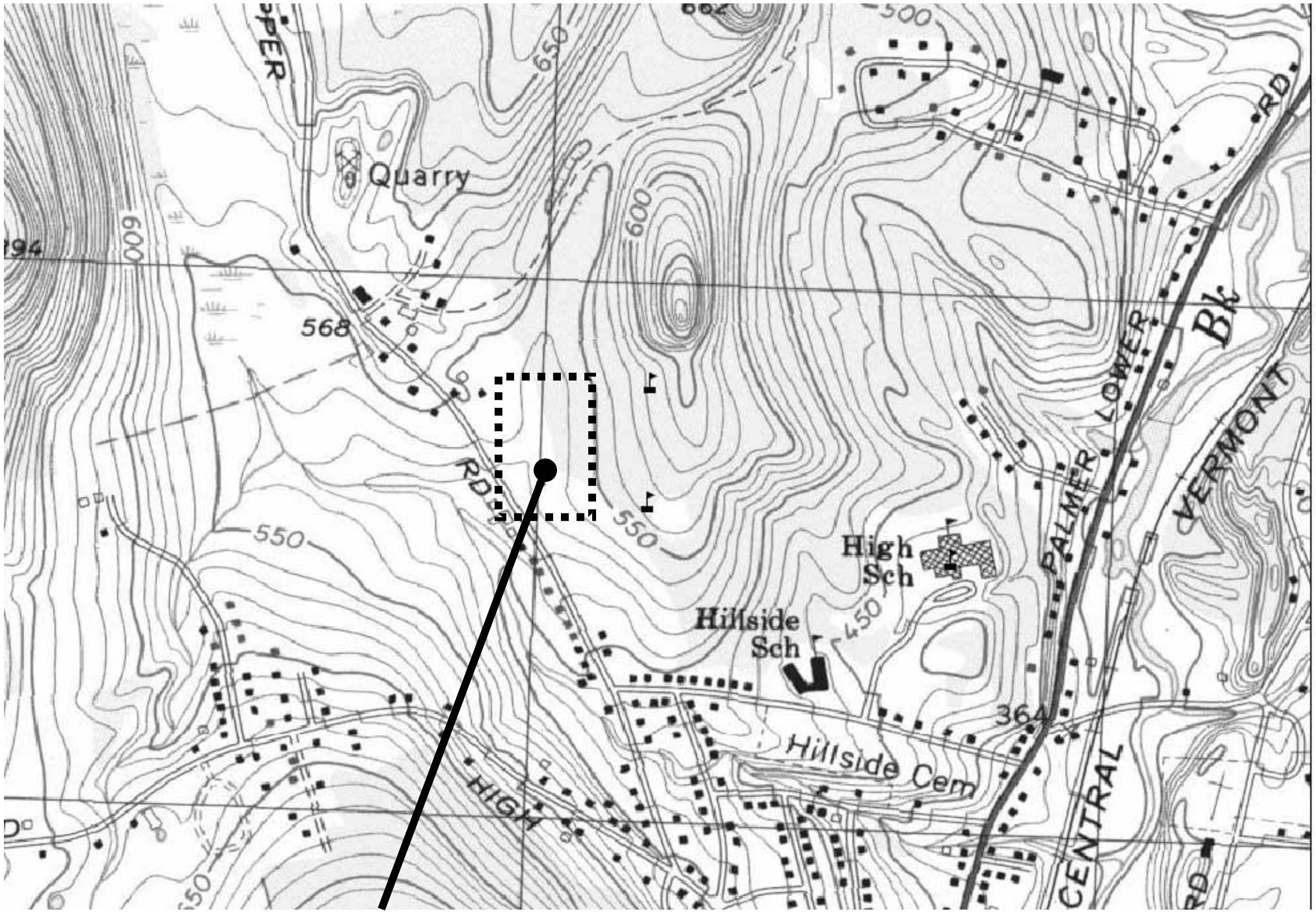
Map 1
Floor Plan of Quarry Hill Community School



F. Quarry Hill School Map

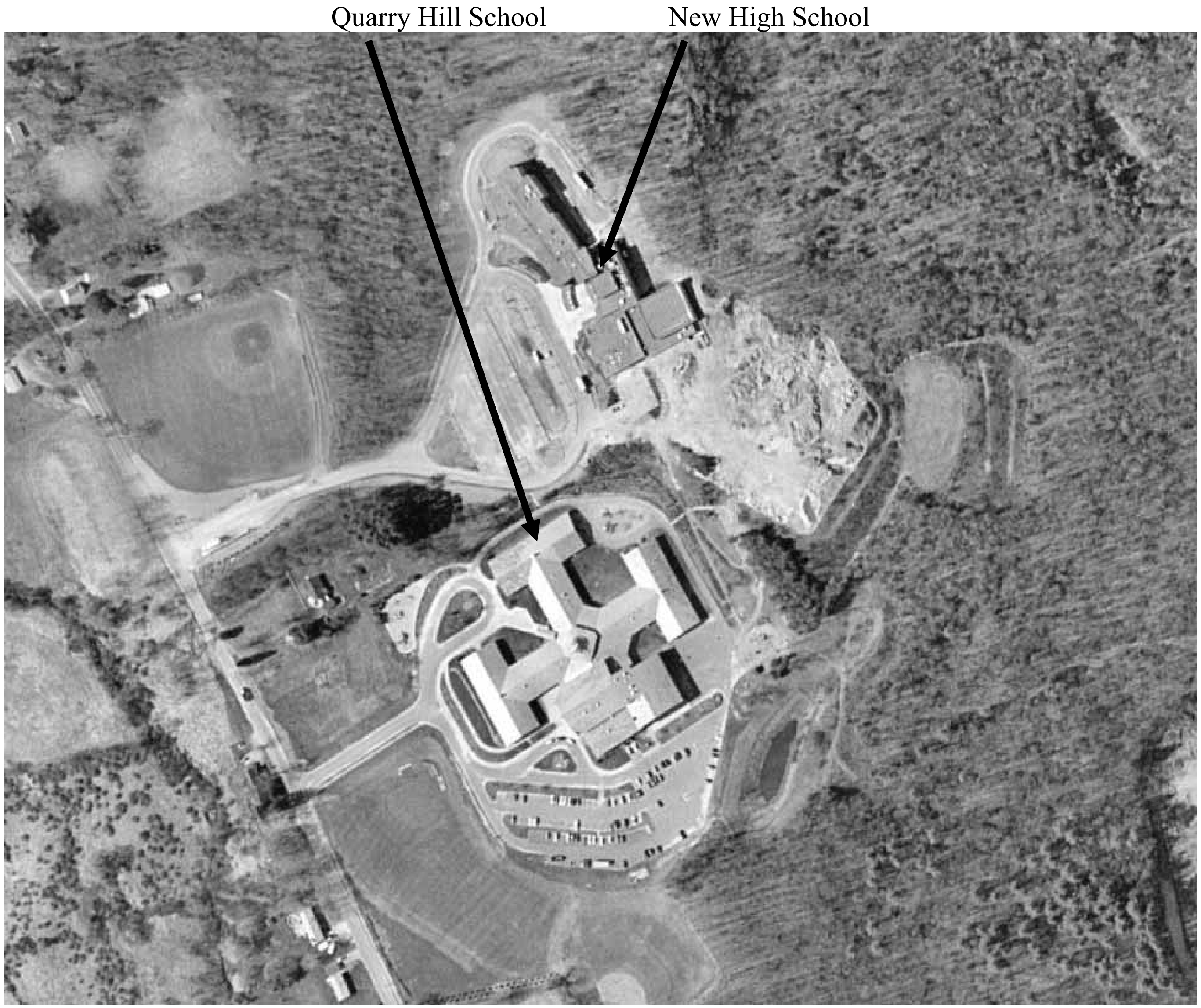
Map 2
Topographic Map of Quarry Hill Community School Area



Quarry Hill Community School Area

Map 3
Aerial View of Map of Quarry Hill Community School Area

Map 4
Close-up Aerial View of Map of Quarry Hill Community School Area



Picture 1

Univents

Picture 2

Extensive Moss Growth on the Building Apron, Slab Exterior Walls and Pilasters

Picture 3

Extensive Moss Growth on the Building Apron, Slab Exterior Walls and Pilasters

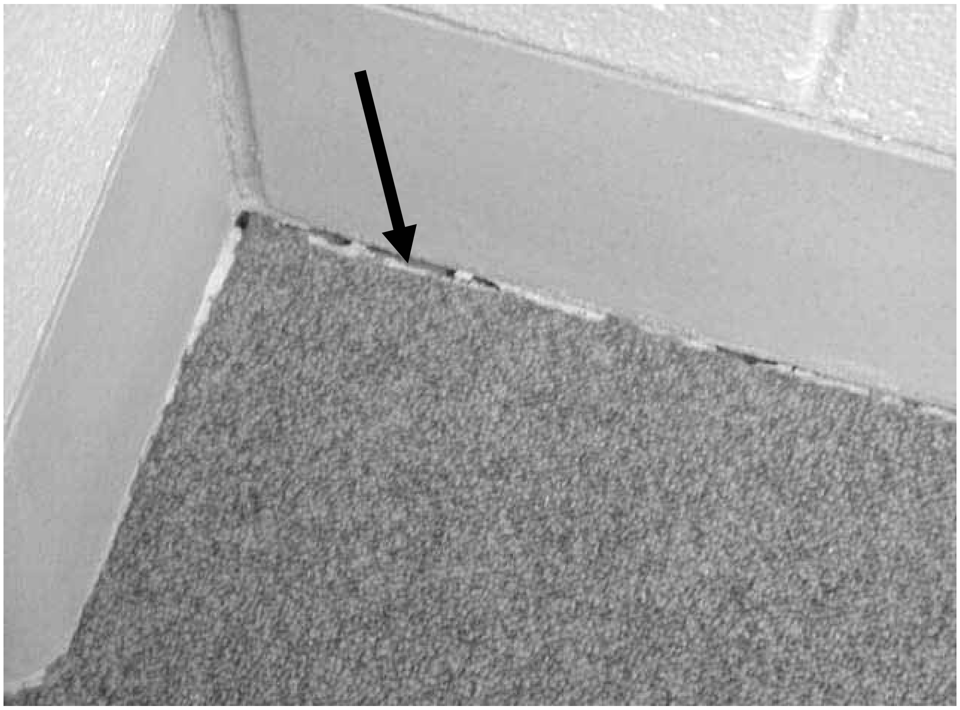
Picture 4

Extensive Moss Growth on the Building Apron, Slab Exterior Walls and Pilasters

Picture 5

Pooling Water against Exterior Wall of School

Picture 6



An Open Seam between the Exterior Wall and Slab

Quarry Hill Community School

43 Margaret Street, Monson, MA 01057

Table 1

Indoor Air Results

May 21, 2004

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (Outdoors)	85	46	415	ND	ND	45	-	-	-	-	
313	77	55	692	ND	ND	46	21	Y	Y Univent	Y Ceiling	Condensation in window, hallway door open
314	76	55	818	ND	ND	57	3	Y	Y Univent	Y Ceiling	Hallway door open; crack in wall
308	78	55	760	ND	ND	55	21	Y	Y Univent	Y Ceiling	PF, hallway door open
312	77	55	485	ND	ND	42	23	Y	Y Univent	Y Ceiling	PF
218	76	54	487	ND	ND	40	0	Y	Y Univent	Y Ceiling	Hallway door open
221	76	52	521	ND	ND	40	0	Y	Y Univent	Y Ceiling	Food storage/use; hallway door open
	77	56	546	ND	ND	55	7	Y	Y Univent	Y Ceiling	Food storage/use. Cleaners; hallway door open

ppm = parts per million
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AD = air deodorizer
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aqua. = aquarium
AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials
design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
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MT = missing ceiling tile
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PC = photocopier
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Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Quarry Hill Community School | **Indoor Air Results**

43 Margaret Street, Monson, MA 01057 | **May 21, 2004**

Table 1

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									Supply	Exhaust	
214	71	52	520	ND	ND	50	13		Y Univent	Y Ceiling	Plant(s) on carpet, breach sink/counter; plants, upholstered furniture, food storage/use (popcorn), wasp nest; supply blocked by clutter
217	77	54	507	ND	ND	45	0	Y	Y Univent	Y Ceiling	Food storage/use, cleaners; hallway door open
420	77	53	750	ND	ND	53	22		Y Univent	Y Ceiling	Food storage/use; hallway door open; supply blocked by plants
421	76	55	667	ND	ND	50	8	Y	Y Univent	Y Ceiling	Plants, upholstered furniture; mice; hallway door open; supply blocked by plants, furniture
402	76	56	569	ND	ND	45	3	Y	Y Univent	Y Ceiling	Hallway door open; supply blocked by furniture
400 Hallway	79	56	524	ND	ND	55	0	N	N	N	
414	77	53	491	ND	ND	43	0	Y	Y Univent	Y Ceiling	Dust, clutter, cleaners; hallway door open; supply blocked by furniture

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									Supply	Exhaust	
418	77	52	618	ND	ND	42	18	Y	Y Off Univent	Y Closet	PF, clutter, cleaners; hallway door open; supply blocked by clutter
212	79	46	505	ND	ND	46	1	Y	Y Univent	Y Ceiling	Upholstered furniture; hallway door open; supply blocked by plants
213	78	50	536	ND	ND	50	1	Y	Y Univent	Y Ceiling	Dirt Box
412	77	50	565	ND	ND	43	1	N	Y Ceiling	Y Ceiling	Hallway door open
413	77	54	784	ND	ND	41-65 in line of PF on	21	Y	Y Off Univent		PF, food storage/use; hallway door open; supply blocked by clutter

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Table 2

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									Supply	Exhaust	
Background (Outdoors)	68	58	364	ND	ND	5	-	-	-	-	
Pool Hallway	74	65	549								
217	76	57	1064	ND	ND	10	19	Y	Y Univent	Y Ceiling	Cleaners; hallway door open; supply blocked by clutter
218	74	57	824	ND	ND	8	16	Y	Y Univent	Y Closet	Hallway door open; cards in bathroom
221	74	57	718	ND	ND	3	18	Y	Y Univent	Y Ceiling	Hallway door open
222	74	56	752	ND	ND	19	17	Y	Y Univent	Y Ceiling	Hallway door open; supply blocked by clutter
225	74	57	952	ND	ND	16	16	Y	Y Univent	Y Closet	Hallway door open; supply blocked by clutter

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									Supply	Exhaust	
226	74	56	1407	ND	ND	20	18	Y	Y Univent	Y Closet	Clutter; supply blocked by furniture
Gym	74	57	540	ND	ND	7	21		Y Ceiling	Y Wall	Hallway door open
Cafeteria	73	58	407	ND	ND	4	9		Y Ceiling	Y	Hallway door open
213	73	53	692	ND	ND	3	1	Y	Y Univent	Y Ceiling	Hallway door open
214	74	58	907	ND	ND	14	12				
318	71	52	649	ND	ND	12	0		Y Univent	Y Ceiling	
317	72	52	883	ND	ND	7	17	Y	Y Univent	Y Ceiling	Clutter, hallway door open
314	74	58	1663	ND	ND	38	23	Y	Y Univent	Y Ceiling	

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Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (μg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
316	72	53	719	ND	ND	13	2	Y	Y Univent	Y	Hallway door open
326	72	55	395	ND	ND		0	Y	Y Univent	Y Ceiling	Hallway door open
328	72	58	577	ND	ND	6	2	Y	Y Univent	Y Ceiling	Clutter, Hallway door open
307	72	55	775	ND	ND	17	1		Y Univent	Y Ceiling	Supply blocked by boxes
308	73	57	971	ND	ND	16	21	Y	Y Univent	Y Ceiling	Hallway door open; supply blocked by plants
428	72	57	548	ND	ND	10	4	Y	Y Univent	Y Ceiling	UF, hallway door open
306	72	58	610	ND	ND	9	1	Y	Y Univent	Y Ceiling	
277	73	55	614	ND	ND	6	0		Y Univent	Y Ceiling	Supply blocked by boxes

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232	73	56	553	ND	ND	4	2	Y	Y Univent	Y Ceiling	Hallway door open
104	73	57	1211	ND	ND	38	23	Y	Y Univent	Y Ceiling	Plants
212	74	52	607	ND	ND	8	2	Y	Y Univent	Y Ceiling	Clutter; supply blocked by plants
320	73	58	885	ND	ND	16	19	Y	Y Univent	Y	Clutter; hallway door open; supply blocked by furniture
321	72	57	856	ND	ND	12	19	Y	Y Univent	Y Ceiling	Hallway door open; supply blocked by furniture
318	72	58	784	ND	ND	7	18	Y	Y Univent	Y Ceiling	Hallway door open; supply blocked by furniture
319	72	58	709	ND	ND	5	21	Y	Y Univent	Y Ceiling	Hallway door open

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									Supply	Exhaust	
414	73	56	1037	ND	ND	9	25	Y	Y Univent	Y off Ceiling	Supply blocked by furniture
415	74	56	1366	ND	ND	17	20	Y	Y Univent	Y Ceiling	Plants; supply blocked by clutter
422	72	55	687	ND	ND	10	0	Y			Pests, hallway door open
413	73	55	922	ND	ND	27	19	Y	Y Off Univent	Y Ceiling	Aqua/terra, plants; hallway door open; supply blocked by clutter
312	73	56	878	ND	ND	16	23	Y	Y Univent	Y Ceiling	Hallway door open; supply blocked by plants
313	73	56	927	ND	ND	8	22	Y	Y Univent	Y Ceiling	Plants, hallway door open
Art Room	72	54	583	ND	ND	11	16	Y	Y Univent	Y	2 water damaged CT, 2 CT w/ visible mold, water damaged other; efflorescence in wall; UF, pets; hallway door open

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408	72	55	723	ND	ND	33	0		Y Univent	Y Ceiling	Supply blocked by clutter
Library	72	54	517	ND	ND	20	18	Y	Y Ceiling	Y Ceiling	Hallway door open
Pool Hallway											Pool odor in hall way outside pool
420	72	54	508	ND	ND	16	23	Y	Y Univent	Y Ceiling	Pests, plants; hallway door open
421	72	54	811	ND	ND	19	22	Y	Y Univent	Y Ceiling	Pets, hallway door open; supply blocked by furniture
418	73	53	792	ND	ND	30	26	Y	Y Univent	Y Ceiling	UF, chicks
419	73	53	820	ND	ND	112	19		Y Off Univent	Y Off Ceiling	Cleaners (Clorox), supply blocked by furniture

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PT & OT	77	53	526	ND	ND	4	0		Y Ceiling	Y Ceiling	PF
417	70	57	456	ND	ND	3	0	Y	Y Univent	Y Ceiling	Clutter; supply blocked by clutter
426	71	59	550	ND	ND	16	0	Y	Y Univent	Y Ceiling	Water damage (other), Efflorescence on mortar, hallway door open; supply blocked by plants
418	77	53	746	ND	ND	65	17	Y	Y Univent	Y Ceiling	Upholstered furniture, clutter; hallway door open; supply blocked by plants
419	77	53	588	ND	ND	51	0	Y	Y Univent	Y Ceiling	Food storage/use, terra, hallway door open; supply blocked by furniture
416	78	52	837	ND	ND	43	21	Y	Y Univent	Y Ceiling	Musty odor, PF, plants, clutter, aqua.; hallway door open; supply blocked by clutter
417	78	54	814	ND	ND	49	23	Y	Y Univent	Y Ceiling	Food storage/use, clutter, terra; hallway door open; supply blocked by plants

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Table 3

Area	Moisture reading in carpet at wall/slab seam %	Moisture reading in carpet 3' from wall/slab seam %	Moisture reading in carpet 5' from wall/slab seam %	Measurement in Seam*
217	ND	ND	-	-
225	9	ND	-	-
226	9	ND	-	-
227	ND	ND	-	19
213	12	ND	-	10
326	ND	ND	-	-
328	15	ND	-	-
212	9	ND	-	23
320	13	ND	-	21
318	10	ND	-	24
319	10	8	ND	12
315	8	ND	-	-
317	9	ND	-	-
314	12	ND	-	-
316	10	10	ND	17
307	10	ND	-	27
308	16	ND	-	-
428	14	ND	-	-
306	19	ND	-	-
414	21	ND	-	-
415	18	ND	-	-
422	25	ND	-	-
Art Room (tile floor)	ND	ND	-	19
408	4	ND	-	-
418	12	ND	-	-
419	ND		-	22

* Moisture Measurements taken from cement between cinderblock in interior hallways consistently measured between 8-10%. Measurements taken within seam above 10% would likely indicate a moisture source impinging on components of seam.

– = Indicates no measurement taken.

ND = non detectable